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The collaboration between Int J Life Cycle Assess and J LCA Jpn

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1 Preamble

The Institute of Life Cycle Assessment Japan (ILCAJ) was established in October 2004. The goal of ILCAJ is to promote academic activities related to life cycle thinking and to share expert knowledge with colleagues from wide ranging backgrounds. Professor Ryoichi Yamamoto, University of Tokyo, has taken responsibility as Chairman of ILCAJ.

In April 2005, ILCAJ has successfully established its publication organ (in Japanese), The Journal of Life Cycle Assessment Japan (J LCA Jpn). The issues appear every 3 months. J LCA Jpn publishes peer-reviewed research articles, commentaries and discussions, (technical) reports, lecture notes, and presentations of research groups in Japan, along with others. In Int J Life Cycle Assess 12(6):348−350, we were happy to announce the collaboration with J LCA Jpn for the purpose of exchanging knowledge, new insights, experiences, and information across the different languages.

The corner JLCA Jpn aims to be a bridge between the LCA community of Japan and that of the whole world. All abstracts of research articles published in J LCA Jpn, as well as commentaries and discussions, will appear in Int J Life Cycle Assess, Corner: JLCA Jpn, in order to introduce Japanese activities to our readers. In addition, some selected research papers from J LCA Jpn will be submitted to Int J Life Cycle Assess for publication following peer review. We hope that this collaboration will stimulate the global exchange of information through professional pathways. The following abstracts were published in J LCA Jpn Vol. 5, No. 4.

Professor Hiroshi Mizutani, Nihon University has become the Editor-in-Chief of J LCA Jpn since January 2009.

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2 Research articles

2.1 Life cycle assessment of super high-yield and conventional rice production systems a comparison based on global warming potential and energy consumption

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Objective The purpose of this paper is to conduct comparative life cycle assessment of super high-yield and conventional rice production systems. Since super high-

yield rice production needs further energy and resource inputs as compared with the conventional production, the judgment of relative superiority should be based on the assessment of whole systems. Therefore, life cycle energy use and life cycle CO_2 emissions are used for the comparison.

Results and discussion Super high-yield rice production consumes much more fuels than conventional production due to drying of the unhulled rice and fertilizer production, and thus it needs much more energy inputs and emits much more greenhouse gases than the conventional production if we use the functional unit of unit area. Energy inputs per hectare were 44 GJ for the super high-yield rice production and 42 GJ for conventional production. GHG emissions per hectare were 8.0 t CO_2 eq. for the super high-yield rice production and 7.5 t CO_2 eq. for the conventional production. However, if we utilize the functional unit of 1 kg of brown rice, we have another result as follows: energy inputs per 1 kg of brown rice were 5.46 MJ for the super high-yield rice production and 7.70 MJ for the conventional production; GHG emissions per 1 kg of brown rice was 1.00 kg CO_2 eq. for the super high-yield rice production, and 1.39 kg CO_2 eq. for the conventional production. That is, energy inputs and GHG emissions per 1 kg of brown rice for the super high-yield rice production were lesser than conventional production. The breakdown of the environmental impacts showed that the production of agricultural machines, materials, fertilizer, agrochemicals, and fuels accounts for more than 70% of all energy inputs. This means that the extension of the lifetime of machines and materials and the reduction of fertilizers and pesticides are effective in reducing energy inputs. In addition, since energy inputs to the drying of the unhulled rice were comparatively large, the reduction of the fuel consumption for drying will be important.

Conclusions This study clarified the environment load of super high-yield and conventional rice production systems. Improving rice yields was considered to be an effective way in decreasing energy inputs and GHG emissions per 1 kg of brown rice. It was shown that we should use the inventory data of rice production for energy in LCA of the biofuel production.

2.2 Reduction in greenhouse gas emissions from process retrofitting and cultivar improvement in combined sugar–ethanol production from sugarcane

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Background, aim, and scope In most sugarcane-producing countries bound by the limitations of arable land, bioethanol is derived from the molasses obtained from sugar production by adding ethanol production processes. Two problems are associated with this approach: the inferior productivity of ethanol and the consumption of fossil fuel for the additional energy demand required for the extended processes. A novel sugar–ethanol combined production process using modified sugarcane, known as "monstercane," has been developed by the authors, which allows for a significant enhancement of ethanol production from molasses after only one extraction of raw sugar instead of the three extractions in the conventional process. Furthermore, due to the enhancement of bagasse productivity, the use of fossil fuel for producing ethanol is eliminated. This study aims to evaluate the greenhouse gas (GHG) emissions induced by the introduction of the conventional and novel processes in Japan, thereby demonstrating the advantages of our approach in applying both process retrofitting and raw material modification to the production of multiple bio-products.

Methods Agricultural and process inventories were established by reviewing the literature and primary data from pilot experiments conducted on Ie island of Okinawa, Japan. LCI was conducted for the production processes of sugar (Case 1), conventional sugar and ethanol (Case 2), and the novel combined sugar–ethanol from the modified sugarcane (Case 3). The impact on global warming was assessed, and comparisons were made of the three cases. The sensitivity of the results to 84 parameters in the inventory model was examined.

Results Cases 2 and 3 resulted in −0.7 and −40.2 ton CO_2 equivalent of GHG emissions per hectare compared to Case 1, respectively. In addition, greater contribution of the modification of sugarcane among other improvements made by retrofitting the processes on the GHG emission reduction was revealed. Several parameters were identified as important in our model, thus those parameters were more closely analyzed, and useful information was obtained for further improvement of process and material.

Discussion The advantage of the combined sugar–ethanol production over a mere recycling of the residue (i.e., third molasses) was elucidated. The results provided directions in further optimization that could make the

most of the land available for production of renewable resources to satisfy multiple needs. Some of the other impact categories, including consumption of fossil fuel and water resources, will also reveal improvements in Case 3 because resources for cultivation remain equivalent, process resource input (fossil fuel) was reduced, and products increased. However, other important impacts, such as emission of pollutants into the air and water, should be further evaluated.

Conclusions The combined bioproduct (e.g., food and fuel) production concept demonstrated in this study would be applicable to exploring a system whose raw material is a crop with emerging applications in addition to conventional applications. The effectiveness of individual applications using the proposed concept can be confirmed with a lifecycle assessment.

Recommendations and perspectives Application of the proposed concept to other biomass utilization systems is recommended. More cases should be explored in sugar–ethanol combined production, for example by changing the production ratio of sugar and ethanol and investigation of how the choice of sugarcane line and the reduction in GHG emissions would be affected. Crops such as sugarcane have a multiple-year cropping cycle; therefore, yields and process inventories should reflect the entire cropping cycle in any successive study.

2.3 Utility of applying carbon footprint at farmers' market aimed at promotion of local production for local consumption

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Objective Recently, many social problems related with food products have risen by several media. Local production for local consumption is paid attention to society from the viewpoint of safety and environment "Carbon footprint", which is the label to show the $LCCO_2$ (life cycle CO_2) emissions of the products, attracts peoples' interests, because it helps citizens to interpret the effect of a product to the environment and is expected to improve the transparency of environmental information. In Japan, it is expected that many products with Carbon footprint will be released to the public. With regard to food products, Carbon footprint might be useful to promote home-grown crops and vegetables, if we could endure the significance of these products using LCA. In this study, we evaluated $LCCO_2$ (CO_2 and N_2O emissions from cultivation stage to sales stage) emissions of six farm products (cabbage, broccoli, spinach, KOMATSUNA, Japanese radish, and sweet potato) and displayed the results using Carbon footprint at farmer's market cooperated with Tsuzuki ward office Yokohama city and Tsuzuki farm (environmental conservation farmer) in Tsuzuki ward. In order to confirm the significance of using LCA, we performed questionnaire survey to see the consumer response after environmental information is disclosed for a certain period.

Results and discussion CO_2 and N_2O emissions of cultivation stage were relatively small, because the farmer we cooperated made it possible to minimize the amount of fertilizer and agrichemicals. Minimizing these amounts might increase risk in smaller amount of crops, but we confirmed that the success of this style of agriculture leads the considerable reduction of CO_2 and N_2O emissions. And there was a big difference of CO_2 emissions between sales at farmers' market and supermarket. Especially, using refrigerator for broccoli and spinach in sales stage in supermarket would be one of the key elements. The questionnaire survey showed that consumers have high interests in the environmental issues and the display of CO_2 emissions. In addition, around 80% of the people answered buying the products which showed the CO_2 emissions rather than those did not show. And we inquired the consumers' willingness to pay (WTP) to the vegetables that showed lower CO_2 emissions. As a result, people have a tendency to pay more for the products with lower CO_2 emissions. We statistically analyzed using X^2 test and F test about this result and confirmed the followings.

1. Carbon footprint could promote the environmental consideration consumer behavior.
2. People have a tolerance to pay for the products with lower CO_2 emissions.

Conclusions In this study, we evaluate $LCCO_2$ emissions of six farm products, and disclosing the environmental information using Carbon footprint at farmer's market in certain period of time. The style of agriculture, the distance of transportation, and the procedure of sales would be key elements for the reduction of environmental impacts. Local production for local consumption using farmer's market would be an effective way to contribute the reduction of it well. According to the result of questionnaire survey, disclosing Carbon footprint would have the potential to promote the environmental consideration consumer behavior, because people evaluated higher values for the products with smaller amount of CO_2 emissions. The next challenge

would be to discuss how to support consumers to interpret the number of CO_2 emissions.

2.4 On the trial allocation in life cycle inventory of structural domestic lumber

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Objective Wood material is widely used for building. Large amount of co-products are generated in sawmill when a log is converted to lumber. Therefore LCI of lumber was implemented based on three allocation procedures (allocation to only lumber, volume-based allocation, and price-based allocation) to know the effect of allocation methods in LCI results and which method is desirable for the LCI of lumber.
Results and discussion CO_2 emission allocated to lumber on volume-based allocation is 30% lower than that on allocation to only lumber. On the contrary, CO_2 emission allocated to lumber on price-based allocation is just 3% lower than that on allocation to only lumber. CO_2 emission allocated to each co-product on volume-based allocation is 5-30 times of that on price-based allocation. From the results of this case study, adapting volume-based allocation to LCI is not proper since it tends to underestimate the environmental load of lumber. Adapting allocation to only lumber and price-based allocation are acceptable from a viewpoint of evaluating the environmental load of lumber. Furthermore, price-based allocation is better from a viewpoint of evaluating the both environmental loads of lumber and co-products. In case of using sawmill residue for fuel in boiler to dry the lumber, similar results were recognized.
Conclusions Adapting price-based allocation is considered most desirable for the LCI of lumber, and allocation to only lumber is acceptable to evaluate the environmental load of lumber. Future work is to investigate the inventory of other wooden materials (e.g., plywood and laminated wood etc.) and to decide which allocation procedure is the best for the inventory of whole wooden materials.

2.5 Modeling of waste transportation for the estimation of energy consumptions and CO_2 emissions by multiple means of transportation

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Objective The waste transportation between regions causes various problems such as the transfer or increase of environmental loads. For example, the amount of waste to treat increases in the receiving regions and the energy consumptions and CO_2 emissions which are accompanied with the waste transportation increases. The main transportation means of waste is by truck, however, countries or areas which are surrounded by bodies of water such as Japan, waste transportation by ship occupies the great importance. In this study, we shall try to construct a waste transportation model with more practical and detailed assumptions than the preceding study (Kagawa, Kondo 2007) by assuming the multiple means of transportation. In this model, we shall consider the energy consumptions and the environmental loads that are necessarily accompanied with the waste transportation between regions.
Results and discussion Based on the related statistical data, we construct an interregional waste transportation model, especially for industrial waste for the intermediate treatment which occupied about 90% of the total amount of waste. First, we compile the amount of interregional waste transportation from a departure to a destination for every combination of prefectures in Japan; which is expressed as a matrix whose row sectors are waste types and column sectors are transportation means. Next, we estimate the distance matrices between prefectures for each transportation means. Then, by multiplying the amount of transported waste by the transportation distance, the amount of transported waste based on freight ton-kilometers is calculated. Finally, from these values we can estimate specific energy consumptions and CO_2 emissions originated from waste transportation. The estimation results show us that generally the waste is transported among neighborhood prefectures. The construction wastes and the waste plastics are typical examples and about 75% of these types of waste are moved by truck. On the contrary, such wastes as dust and cinders are transported by ship for great distance. In freight ton-kilometers basis, the Chubu block exports large amount of waste to other blocks. On the contrary, the Kyushu block imports large amount of waste from other blocks. Exports from the Kanto, Chubu, and Kinki blocks to the Chugoku block are also large. The Hokkaido and Kanto block also

import wastes from the Hokkaido, Kanto, and Chubu blocks. Dust is exported from all blocks to the Shikoku and Kyushu blocks. With respect to the means of transportation the exports by ship to the Kyushu block are significantly large. We find that about 92% of energy consumptions and CO_2 emissions are attributed to the transportation by truck, although the freight based on ton-kilometer by truck and by ship are about 56% and 44%, respectively.
Conclusions In this study, we constructed an interregional waste transportation model by assuming the multiple means of transportation. The results of estimation show that energy consumptions and CO_2 emissions accompanied with interregional waste transportation are, largely, dependent on truck transportation. It is clear that the change of the transportation system is fundamentally important for the reduction of environmental loads. Our next objective will be the estimation of the impact of the transportation of the industrial waste for landfilling. Consideration of other environment loads such as NO_X, SO_X, and SPM, and the scenario analysis for various choices of waste transportation system are also important. We will also try to apply this model to the interregional waste input–output analysis.

2.6 Inventory analysis of waste management including bio-waste recycling in Kariya and Chiryu cities

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Objective Environmental impact of waste processing including bio-waste recycling of Kariya and Chiryu cities, Aichi prefecture was quantitatively analyzed by LCA procedure to propose the future waste management. In this study, the system boundary covers the generation, collection, treatment, recycling, and landfill of municipal solid waste. We employed three scenarios for future waste management to evaluate the amount of GHG emission and landfill. Scenario-1, 2, and 3 introduced waste food oil recycling to biodiesel fuel, kitchen garbage recycling to bioethanol, and combustible waste recycling to bio-gas, respectively.
Results and discussion Brief outline of each scenario is as follows; in the case of scenario-1 the amount of GHG emission somewhat decreases due to the use of biodiesel fuel, in the case of scenario-2 that of GHG emission is not decreased because the consumption of bioethanol is small quantity and the amount of incinerated ash is not decreased, and in the case of scenario-3 that of GHG emission decreases due to the use of bio-gas truck fuels and the introduction of bio-gas power generation, and that of incinerated ash is not decreased.
Conclusions It is thought that combination of scenario-1 and scenario-3 is desirable for the future waste management of Kariya and Chiryu cities because bio-waste recycling is effective to reduce the GHG emission.

2.7 CO_2 reduction potentials by utilizing waste plastics in steel works

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Background, aim, and scope Feedstock recycling has received attention as an effective method to recycle waste plastics. However, estimating the reduction potential by LCA using coke oven and blast furnace in steel works has been a challenging task due to the complex structure of energy flow in steel works. Municipal waste plastics consist of several plastic resins. Previous studies have generally disregarded the composition of waste plastics, which varies significantly depending on the geographical area. If the reduction potentials by using each plastic resin in steel works can be quantified, the potential of municipal waste plastics (mixtures of plastic resins) can be estimated by summing up the potential of each resin multiplied by the composition of each resin in municipal waste plastics. Therefore, the goal of this study is to investigate the reduction potentials of CO_2 emissions by using individual plastic resins (PE, PP, PS, and PET) and those for municipal waste plastics in the coke oven and blast furnace.
Materials and methods A model was developed to clarify the energy flow in steel works. In order to estimate the changes in energy and material balance in coke ovens when waste plastics are charged, the equations to calculate the coke product yield, gas product yield, and oil product yields of each plastic resin were derived from previous studies. The Rist model was adopted to quantify the changes in the inputs and outputs when plastics were fed into a blast furnace. Then, a matrix calculation method was used to calculate the change in energy balance before and after plastics are fed into a coke oven.
Results It was confirmed that product yields of municipal waste plastics (mixtures of plastic resins) could be estimated by summing up the product yield of each plastic resin multiplied by the composition of each resin in municipal waste plastics. In both cases of coke oven and blast furnace feedstock recycling, the reduction potential of CO_2 emissions varies significantly depending on the plastic resins. For example, in the case of coke oven chemical

feedstock recycling, the reduction potential of PS and PP is larger than that of PE. On the other hand, in the case of blast furnace feedstock recycling, PE has the largest CO_2 emissions reduction potential, whereas, the CO_2 emission reduction potential of PP is smaller than those of PE and PS. In both cases, PET has negative CO_2 emission reduction potentials, i.e., there is an increase of CO_2 emissions. In addition, the reduction potentials of CO_2 emissions are slightly different in each city.

Discussions The differences in the reduction potentials of CO_2 emissions by coke oven chemical feedstock recycling of each plastic resin is attributable to the differences in calorific values and coke product yields of each plastic resin. On the other hand, the difference in the CO_2 emission reduction potential for each plastic resin in blast furnace feedstock recycling is attributable to the difference in calorific values and the carbon and hydrogen content of each plastic resin, which leads to a difference in the coke substitution effect by each plastic resin. In both cases, the difference in those of municipal waste plastics is mostly attributable to the amount of impurities (e.g., ash, water) in the municipal waste plastics.

Conclusions It was found that the reduction potential of CO_2 emissions by coke oven and blast furnace feedstock recycling of municipal waste plastics (mixtures of plastic resins) could be estimated by summing up the potential of each resin multiplied by the composition of each resin in municipal waste plastics. It was also clarified that feedstock recycling of waste plastic in steel works is effective for avoiding the increase in CO_2 emissions by incinerating waste plastics, such as those from household mixtures of different resins.

Recommendation and perspectives With the results obtained in this study, reduction potentials of CO_2 emissions can be calculated for any waste plastics, because differences in composition are taken into account.

2.8 Evaluation of bioethanol production system from rice straw

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Objective Ethanol production from lignocellulosic biomass such as rice straw and wood are recently getting high attention. In this study, we evaluated energy consumption, CO_2 emissions and cost of the ethanol production from rice straw by concentrated sulfuric acid hydrolysis throughout the life cycle and compared its results with gasoline. For the system boundary of the life cycle of bioethanol, it is necessary to consider each process of the bioethanol production system including cultivation, harvesting, collection/transportation, fuel conversion, fuel transportation, and fuel use. However, in this study, the cultivation process is not considered because we exclusively evaluate unused rice straw from agricultural residues. We considered harvesting, collection/transportation of rice straw, and conversion of ethanol, transportation of ethanol, lignin boiler, waste disposal, liquid waste treatment process, and ethanol use. Beside the operation processes the construction of an ethanol plant, the rice straw collection/transportation vehicles, and the ethanol transportation vehicles were considered. Furthermore, we analyzed the influence of the rice straw cost and capacities of the bioethanol plant on the ethanol production cost.

Results and discussion The energy consumption was estimated to be 728 MJ, and CO_2 emissions were estimated to be 39 kg CO_2 per production of 1 GJ of ethanol. Energy input and CO_2 emissions of the ethanol conversion process were the most aspects of the life cycle of ethanol. Bioethanol uses about 39% less energy and produces 51% less CO_2 emissions than gasoline. Lignin residue combustion has a high potential for reducing energy consumption and CO_2 emissions. The bioethanol cost was estimated to be 181 JPY/L. The rice straw cost and its conversion cost account for 68% and 30% of the total cost, respectively. In terms of cost, ethanol is not competitive with gasoline. However, if ethanol becomes tax-exempt from the gasoline tax, the ethanol price can become competitive for the end user.

Conclusions From the viewpoint of energy consumption and CO_2 emissions, bioethanol is likely superior to gasoline. The system which utilizes lignin in a boiler and recovers heat effective increases the energy balance and reduces CO_2 emissions. Since the rice straw collection/transportation cost accounts for a large part of the total cost in the ethanol production system, it is significant to make the price competitive. The development of low-cost technologies to collect rice straw and ethanol conversion as well as a financial support system are needed.

2.9 Environmental analysis for international marathon event based on the life cycle perspectives

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Objective Interests in the assessment for events are increasing rapidly. Environmental impacts caused by several events like sports tournaments, music festivals, and international conferences have already been assessed.

The publications of these results contribute to promote the reduction of CO_2 emission. Through these activities, various problems with regard to the assessment, especially the following problems have been raised.

- Quickness of analysis: hopefully, the temporary result should be presented on the day of the event in order to promote environmental communication.
- Comprehensiveness of analysis: the scope of LCA should cover as far as possible in order to avoid underestimate the result. Some of big events include thousands of items.

We assessed Tokyo marathon 2008 using hybrid LCA applying CO_2 intensities obtained by input–output method and process method. More than 2,000 items were covered. Transportation, accommodation, food, advertisement, security, management, measurement, entry, waste management, and office were included in the scope of this study.
Results and discussion The total amount of CO_2 emission including direct and indirect emissions was calculated as 5,000 ton. The environmental burdens of transportation occupied a half of total amounts. The contribution of airplane used by participants from foreign countries was estimated high, although the number of these people was less than 5% of total. The emission caused by equipments such as the stands, temporary lavatory, and fence used in the starting point, the effects of finish point and the marathon course were also estimated high. The CO_2 emission caused by commemorative products like T-shirt and medals given to runners were also important, because a number of products had to be produced. Environmental burdens related to services like rental, volunteers, and guard were also high. The effects of activities for environment implemented by organizer were assessed. These results will be used to reduce CO_2 emission in the next time.
Conclusions LCA for large-scale sports event was carried out using hybrid approach. This approach enabled us to obtain the calculated result quickly. Temporary result was released to the public on the day of the event. Final result was obtained after the fixed data were provided to the practitioners. Through this process, it became possible to share environmental information among various stakeholders like runner, organizer, and audience effectively.

2.10 Life cycle analysis of photovoltaic modules with recycling processes

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Objective Recycling of photovoltaic cell will become more important in the near future because of rapid growth of PV installation since the 1990s. It is needed to evaluate the effect of PV recycling from the economical and environmental points of view. In this paper, input energy, CO_2 emissions and capital costs for the production of photovoltaic modules with recycling process are evaluated using a life cycle analysis method. Furthermore, annual production and installed cost for PV modules are estimated until 2050 when PV recycling plants is installed.
Results and discussion The lifecycle input energy of the recycling PV module decreases 20% and 71% for the thermal decomposition and the nitric acid treatment, respectively, comparing with the unrecycling one. The CO_2 emission and the cost are also decreased by the introduction of recycling processes. The cost of the nitric acid treatment is low, and the PV module cost decreases 41%. The result of estimation of the annual production and the installed cost for PV modules with the nitric acid treatment shows reasonable cost on 2017 or later.
Conclusions It was supposed to be difficult to recycle by the thermal decomposition because of cost for the process. Based on the results of the evaluations performed in this study, however, the nitric acid treatment is desirable for PV module recycling. The nitric acid treatment can be expected as a main process of future solar cell recycling due to the lower input energy, the CO_2 emission, and the system cost. PV module recycling is anticipated a practical application in the near future.

2.11 Evaluation method of data quality for background data in LCA

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Objective To attain higher efficiency in expediting LCA researches, it is inevitable to utilize background data wherever environmental load is considered small. For this reason, development of background database should be an issue of utmost urgency; but in fact, much inventory data collection still has to be done. Presently, background database are often found built up on the ground of inventory data that are inconsistent in data origins; which may affect reliability of thus-developed database. If not enough careful consideration is given to this fact, LCA studies can most likely result in serious misinterpretation. Data quality management of background data is, therefore, indispensable for every LCA researcher when self-evaluation or verification of his/her LCA study is sought after. Objective of our study was to develop a practical method that is useful for evaluation/verification of the quality of various exiting background data. Coping with the limited availability of information on data

quality studies, priority was given to developing a practical method that could help an easy and general evaluation of background data quality.

Results and discussion

1. Factors required for more reliable background data were selected referring to the data quality requirements of ISO for inventory data. Then problems in existing data quality were discussed. ISO's requirements of inventory data are coverage, completeness and representativeness of the data, consistency and reproducibility of the method, sources of the data, uncertainty of the information, and so on. In contrast, many factors of existing data like consistency, reproducibility, and uncertainty were unknown for lack of data information.
2. The method of data quality management for background data was proposed. In this method, background data from each data source is evaluated in quality from comprehensiveness of input data and range of coverage. The former is classified into five levels; the latter is classified into four.
3. More than 900 existing data were evaluated using the method, and the overall quality of existing data was profiled.
4. Future assignments in management of background data quality were discussed based on the study above. Efforts are to be made to record information related to data quality, to make a set of rules to improve data quality and so on.

Conclusions The method of data quality evaluation for management of existing background data was developed, so that can evaluate the quality broadly and easily. This will help select most suitable data and make more accurate LCA data analyses.